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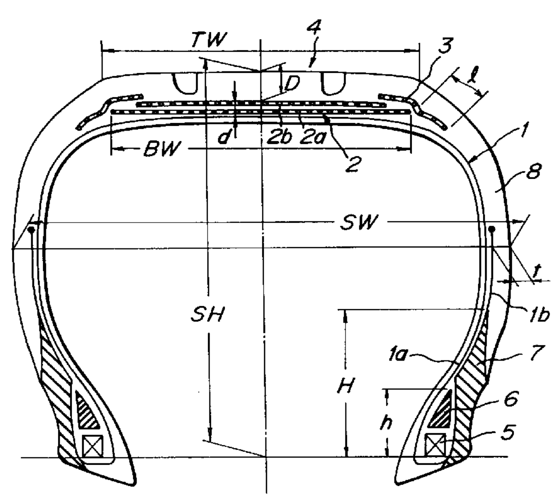
(54) **Pneumatic radial tires.**

(57) A pneumatic radial tire comprises a tread portion (4) of cap and base structure, a pair of sidewall portions (8), a pair of bead portions, a radial carcass (1) of at least one carcass ply, and a belt (2) of two cross belt cord layers (2a, 2b), and is further provided with a particular inner liner (10) and/or at least one particular auxiliary layer (3) arranged on each side region of the belt. In this tire, a ground contact width (TW) of the tread portion (4) is within a range of 0.55-0.70 of the maximum width (SW) of the tire, and a rubber gauge (D) of the tread portion is within a range of 0.05-0.08 of a tire height (SH) as measured from a bead base of the bead portion, and the sidewall portion (8) has a rubber gauge (t) of 1.0-2.5 mm.

FIG_1



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This invention relates to a pneumatic tire usable for passenger cars, and more particularly to a pneumatic radial tire which can realize low fuel consumption of a vehicle by reducing the rolling resistance and weight of the tire.

As a means for reducing the rolling resistance of the tire, there is a reduction of tire weight. For this purpose, there is proposed a method of thinning a rubber gauge in a tread portion of the tire.

According to such a conventional technique, the rolling resistance becomes smaller as the rubber gauge in the tread portion becomes thinner. However, when the rubber gauge is less than a specific value, the rolling resistance as well as the wear resistance and ride comfortability of the tire are inconveniently degraded, so that it is difficult to simultaneously establish the reduction of the rolling resistance and the improvements of the wear resistance and ride comfortability.

That is, when the rubber gauge in the tread portion becomes too thin for the reduction of the tire weight, the bending rigidity of the tread portion at a section in the widthwise direction of the tire lowers to create a difference in a rotating diameter of the tire between a central region and each side region of the tread portion because the ground contacting length of the tread surface is short in the central region and long in the side region. As a result, a large bending deformation at the section in the widthwise direction is produced in the side regions during the rotation of the tire to increase the strain of the tread and hence the rolling resistance.

In the conventional pneumatic radial tire for passenger car, it is general that the minimum thickness of the innerliner is not less than 0.7 mm and the material thereof is chlorobutyl rubber. The innerliner occupies about 5% of the tire weight, and also the lowering of practical performances such as steering stability, ride comfortability and the like hardly occurs even if the thickness of the innerliner is made thin, so that it is considered that the thinning of the innerliner is effective to reduce the tire weight and the rolling resistance of the tire. In the conventional radial tire, however, the innerliner is obliged to have a minimum thickness of not less than 0.7 mm in connection with an air barrier, so that the sufficient reduction of tire weight is not yet attained.

In general, the pneumatic radial tire comprises a belt of two or more belt layers each containing steel cords therein, so that there is a problem that it is difficult to attain low fuel consumption because the tire weight becomes large. Further, even if it is intended to reduce the fuel consumption by thinning the thickness of the tread portion or narrowing the width of the steel belt layer, the expected low fuel consumption can not be attained. In addition, the thickness of the tread portion is thinner and the rigidity of the belt is low to increase input from road surface, so that there is caused a problem of increasing road noise.

It is, therefore, an object of the invention to solve the aforementioned problems of the conventional technique and to provide a novel pneumatic radial tire capable of effectively reducing the rolling resistance.

It is another object of the invention to provide a novel pneumatic radial tire capable of attaining low fuel consumption and effectively reducing road noise.

According to a first aspect of the invention, there is the provision of a pneumatic radial tire comprising a tread portion of cap and base structure, a pair of sidewall portions extending inward from tread ends in a radial direction of the tire, a pair of bead portions extending from the sidewall portions, a carcass of at least one carcass ply extending between the bead portions and containing cords substantially arranged at an angle of 90° with respect to a circumferential direction of the tire, a belt of two belt layers each containing cords arranged at a relatively small cord angle with respect to the circumferential direction, cords of which layers being crossed with each other and at least one auxiliary layer disposed on each side portion of the belt and extending toward a sidewall portion over a position of maximum width of the belt, characterized in that the belt has a width corresponding to 70-110% of ground contact width of the tread portion, and the tread portion has a rubber gauge corresponding to not more than 4.5 times of a thickness of the belt, and the auxiliary layer is comprised of cords substantially extending in the circumferential direction, in which a Young's modulus of the cord is smaller than that of the cord in the belt and a periphery length of a portion extending from the maximum width of the belt toward the sidewall portion in the auxiliary layer is within a range of 8-15% of the width of the belt.

According to a second aspect of the invention, there is the provision of a pneumatic radial tire comprising a tread portion of cap and base structure, a pair of sidewall portions extending inward from tread ends in a radial direction of the tire, a pair of bead portions extending from the sidewall portions, a carcass of at least one carcass ply extending between the bead portions and containing cords substantially arranged at an angle of 90° with respect to a circumferential direction of the tire, a belt of two belt layers each containing cords arranged at a relatively small cord angle with respect to the circumferential direction, cords of which layers being crossed with each other and an innerliner, characterized in that a ground contact width of the tread portion is within a range of 0.55-0.70 of a maximum width of the tire, and a rubber gauge of the tread portion is within a range of 0.05-0.08 of a tire height as measured from a bead base of the bead portion, and a base rubber of the tread portion has tan δ of 0.02-0.07, and the sidewall portion has a rubber gauge of 1.0-2.5 mm and tan δ of 0.02-0.15, and the innerliner is made from brominated butyl rubber and has a thinnest portion of 0.2-0.7 mm.

According to a third aspect of the invention, there is the provision of a pneumatic radial tire comprising a tread portion of cap and base structure, a pair of sidewall portions extending inward from tread ends in a radial direction of the tire, a pair of bead portions extending from the sidewall portions, a carcass of at least one carcass ply extending between the bead portions and containing cords substantially arranged at an angle of 90° with respect to a circumferential direction of the tire, a belt of two belt layers each containing cords arranged at a relatively small cord angle with respect to the circumferential direction, cords of which layers being crossed with each other and an innerliner, characterized in that a ground contact width of the tread portion within a range of 0.55-0.70, preferably 0.60-0.65 of a maximum width of the tire, and a rubber gauge of the tread portion is within a range of 0.05-0.08, preferably 0.065-0.075 of a tire height as measured from a bead base of the bead portion, and a base rubber of the tread portion has tan δ of 0.02-0.07, preferably 0.03-0.05, and the sidewall portion has a rubber gauge of 1.0-2.5 mm, preferably 1.5-2.2 mm and tan δ of 0.02-0.15, preferably 0.05-0.09, and a radially inner belt layer of the belt is comprised of steel cords and a radially outer belt layer thereof is comprised of organic fiber cords such as aramide fiber cords or the like and is folded at its side ends inward in a widthwise direction of the tread portion, and the innerliner is made from brominated butyl rubber and has a thinnest portion of 0.2-0.7 mm, preferably 0.3-0.4 mm.

According to a fourth aspect of the invention, there is the provision of a pneumatic radial tire comprising a tread portion, a pair of sidewall portions extending inward from tread ends in a radial direction of the tire, a pair of bead portions extending from the sidewall portions, a carcass of at least one carcass ply extending between the bead portions and containing cords substantially arranged at an angle of 90° with respect to a circumferential direction of the tire, and a belt of two belt layers each containing cords arranged at a relatively small cord angle with respect to the circumferential direction, cords of which layers being crossed with each other, characterized in that a ground contact width of the tread portion within a range of 0.55-0.70 of a maximum width of the tire, and a rubber gauge of the tread portion is within a range of 0.05-0.08 of a tire height as measured from a bead base of the bead portion, and a rubber of the tread portion has tan δ of 0.02-0.07, and the sidewall portion has a rubber gauge of 1.0-2.5 mm, and a rubber gauge at a position separated from a ground contact end of the tread portion toward the bead portion at a distance as a periphery length of 3-10 mm is within a range of 60-70% of the rubber gauge of the tread portion and a rubber gauge at a position further separated from the above position toward the bead portion at a distance corresponding to 12-17% of a periphery length ranging from a contact end of the bead portion with a rim flange to the contact end of the tread portion is within a range of 40-50% of the rubber gauge of the tread portion.

The term "rubber gauge of the tread portion" used herein means a thickness of tread rubber inclusive of skid base rubber measured at a center of the tread portion, and the term "rubber gauge of the sidewall portion" used herein means a rubber gauge measured at a position corresponding to the maximum tire width.

The invention will be described with reference to the accompanying drawings, wherein:

Fig. 1 is a radially sectional view of a first embodiment of the pneumatic radial tire according to the invention;

Fig. 2 is a schematic view conceptionally illustrating an apparatus for measuring a coefficient of rolling resistance in the tire;

Fig. 3 is a radially sectional view of a second embodiment of the pneumatic radial tire according to the invention;

Fig. 4 is a radially sectional view of a third embodiment of the pneumatic radial tire according to the invention;

Fig. 5 is a graph showing a distribution of sound pressure of road noise frequency;

Fig. 6 is a radially sectional view of a fourth embodiment of the pneumatic radial tire according to the invention; and

Figs. 7a and 7b are schematically partial section views showing another embodiments of thin rubber gauge portion at side end region of the tread portion.

In the pneumatic radial tire of the first aspect, the difference in the ground contact length between the central region and the side region in the tread is made sufficiently small by adequately selecting the belt width, tread rubber gauge, auxiliary layer width, extension direction of cords in the auxiliary layer and the like, whereby the rolling resistance of the tire can effectively be reduced.

The reason why the belt width is within a range of 70-110% of ground contact width of the tread portion is due to the fact that when the belt width is less than 70% of the ground contact width, the tread portion can not be reinforced over its full width and hence the ground contact length of the side region of the tread portion can not effectively be reduced, while when it exceeds 110%, there is no effect on the improvement of the ground contact shape of the tread portion and hence the rolling resistance and also the tire weight undesirably increases.

When the rubber gauge of the tread portion exceeds 4.5 times of the thickness of the belt, the ground

contact length of the central region of the tread portion becomes too long as compared with the ground contact length of the side region of the tread portion to undesirably increase the rolling resistance.

In this tire, at least one auxiliary layer disposed on each side end of the belt and extending over the position corresponding to the maximum belt width toward the sidewall portion is comprised of cords substantially extending in the circumferential direction of the tire and the Young's modulus of the cord in the auxiliary layer is made smaller than that of the cord in the belt layer, whereby the bending deformation in the widthwise direction of the tire at the ground contact area during the running of the tire is decreased to reduce the rolling resistance.

Further, the periphery length of the portion of the auxiliary layer extending from the position of the maximum belt width toward the sidewall portion is made within a range of 8-15% of the belt width, whereby the rolling resistance of the tire can more effectively be reduced.

When the periphery length is less than 8%, the bending deformation of the tread portion in the widthwise direction can not effectively be controlled and hence the rolling resistance of the tire can not be reduced, while when it exceeds 15%, the deformation of the sidewall portion becomes large and the tire weight undesirably increases and hence it is obliged to increase the rolling resistance.

In the pneumatic radial tire of the second aspect, the tire weight and the rolling resistance can effectively be reduced by adequately selecting the ground contact width and rubber gauge of the tread portion, rubber gauge of the sidewall portion, tan δ of tread base rubber and sidewall rubber and the like and combining them.

In this tire, the thinnest portion of the innerliner is made to have a thickness of 0.2-0.7 mm, whereby the tire weight can be more reduced and internal loss can effectively be decreased. Further, the innerliner is made from brominated butyl rubber, so that even if the thickness is thin, air leakage can very effectively be prevented.

When the ground contact width of the tread portion is less than 0.55 of the maximum tire width, it becomes too narrow to degrade the wear resistance and steering stability, while when it exceeds 0.70 of the maximum tire width, the weight of the tread portion and the rolling resistance increase to degrade the fuel consumption.

When the rubber gauge of the tread portion is less than 0.05 of the tire height, it becomes too thin to degrade the wear resistance, ride comfortability and the like, while when it exceeds 0.08 of the tire height, the weight and internal loss increase to degrade the fuel consumption.

When tan δ of the base rubber in the tread portion is less than 0.02, the crack resistance and cut resistance are degraded to lower the durability, while when it exceeds 0.07, the internal loss increases to degrade the fuel consumption.

Further, when the rubber gauge of the sidewall portion is within a range of 1.0-2.5 mm, the weight of the sidewall portion is sufficiently reduced while giving satisfactory cut resistance to the sidewall portion. If it is less than 1.0 mm, the sufficient cut resistance and the like can not be maintained, while if it exceeds 2.5 mm, the weight becomes too large.

When tan δ of the rubber in the sidewall portion is less than 0.02, the cracking is apt to be caused, while when it exceeds 0.15, the internal loss becomes too large to degrade the fuel consumption.

When the thickness of the thinnest portion of the innerliner is less than 0.2 mm, a risk of causing air leakage becomes high, while when it exceeds 0.7 mm, the sufficient weight reduction and low internal loss can not be attained.

The pneumatic radial tire of the third aspect is a modified embodiment of the second aspect. In this case, the belt is comprised of a radially inner belt layer containing steel cords therein and a radially outer belt layer containing organic fiber cords therein, whereby the tire weight can further be reduced. Further, the outer belt layer is folded at both side ends, whereby road noise actualized in accordance with low fuel consumption can effectively be reduced.

The pneumatic radial tire of the fourth aspect is substantially another modified embodiment of the second aspect. In this case, the rubber gauge is decreased between a position separated from a ground contact end of the tread portion toward the bead portion at a distance as a periphery length of 3-10 mm and a position further separated from the above position toward the bead portion at a distance corresponding to 12-17% of a periphery length ranging from a contact end of the bead portion with a rim flange to the contact end of the tread portion, whereby the reduction of tire weight and high flexibility can be attained to realize the reduction of the rolling resistance and the improvement of the ride comfortability.

The reason why the outward end of the rubber gauge decreased portion in the radial direction of the tire is located at a distance of 3-10 mm from the ground contact end of the tread portion is due to the fact that when the distance is less than 3 mm, the rigidity of the tread end portion becomes too low to prematurely cause abnormal wear in the tread portion and also the rubber gauge becomes too thin in the vicinity of the belt end to degrade the durability, while when it exceeds 10 mm, the rigidity in the vicinity of the tread end portion can not properly be decreased and the sufficient flexibility can not be obtained.

Further, the reason why the inward end of the rubber gauge decreased portion in the radial direction of

the tire is located at a position separated from the position of the outward end over a distance corresponding to 12-17% of the periphery length is due to the fact that when the distance is less than 12%, the length of the rubber gauge decreased portion becomes too short to insufficiently attain the low fuel consumption and the improvement of ride comfortability, while when it exceeds 17%, the length of the rubber gauge decreased portion becomes too long to excessively lower the rigidity between the tread portion and the sidewall portion and degrade the steering stability.

Moreover, the reason why the rubber gauge at the outward end is 60-70% of the rubber gauge of the tread portion is due to the fact that when it is less than 60%, the rubber gauge decreased portion becomes too thin and comes near the belt end to degrade the durability (or resistance to separation failure at belt end), while when it exceeds 70%, the effect of decreasing the rigidity is insufficient. On the other hand, the reason why the rubber gauge at the inward end is 40-50% of the rubber gauge of the tread portion is due to the fact that when it is less than 40%, the rubber gauge decreased portion becomes too thin to degrade the durability (or side cut resistance), while when it exceeds 50%, the effect of decreasing the rigidity is insufficient.

In Fig. 1 is sectionally shown a first embodiment of the pneumatic radial tire according to the invention, in which numeral 1 is a radial carcass of a single carcass ply and numeral 2 a belt superimposed about a crown portion of the carcass 1 and composed of two belt layers 2a, 2b.

In the belt 2, cords of the two belt layers 2a, 2b are extended at a relatively small cord angle with respect to the circumferential direction of the tire and crossed with each other. Furthermore, the inner belt layer 2a has a width wider than that of the outer belt layer 2b.

Further, an auxiliary layer 3 is disposed on each side region of the belt 2 and extended over a position of maximum width of the belt 2 toward a sidewall portion 8 of the tire.

A tread rubber is arranged on the belt 2 and the auxiliary layer 3 to form a tread portion 4. The width BW of the belt 2 is within a range of 70-110% of a ground contact width TW of the tread portion 4, while the rubber gauge D of the tread portion 4 is not more than 4.5 times of a thickness d of the belt 2 including a thickness of coating rubber.

The auxiliary layer 3 is comprised of cords extending substantially in the circumferential direction of the tire, in which Young's modulus of these cords is made smaller than that of the cord in the belt layer and a periphery length ℓ of a portion in the auxiliary layer 3 extending from a position of maximum belt width toward the sidewall portion is within a range of 8-15% of the belt width BW.

According to the tire of the above structure, the difference in the ground contact length between the central region and the side region in the tread portion is made sufficiently small as previously mentioned, whereby the rolling resistance of the tire can effectively be reduced.

Moreover, in order to more reduce the rolling resistance of such a tire, it is preferable to add the following conditions to the above structure.

That is, each end portion of the carcass 1 is wound around a bead core 5 from inside of the tire toward outside thereof, while a bead filler 6 is disposed outside the bead core 5 between a main body 1a and turnup portion 1b of the carcass 1 and a rubber chafer 7 is arranged outside the turnup portion 1b.

Moreover, the rubber gauge D of the tread portion 4 is within a range of 0.05-0.08, preferably 0.065-0.075 of a tire height SH as measured from bead base of the bead portion, and the ground contact width TW of the tread portion 4 is within a range of 0.55-0.70, preferably 0.60-0.65 of a maximum tire width SW, and tan δ of cap rubber for the tread portion 4 is 0.07-0.15, and tan δ of base rubber for the tread portion 4 is 0.02-0.07, and the rubber gauge t of the sidewall portion 8 at a position of the maximum tire width SW is within a range of 1.0-2.5 mm, preferably 1.5-2.2 mm. In addition, a height h of the bead filler 6 measured from the bead base is lower than a height H of the rubber chafer 7 measured from the bead base, while a volume ratio of the bead filler 6 to the rubber chafer 7 is within a range of 10-40%, preferably 20-30%.

In this case, the rubber chafer 7 has a maximum thickness at a position substantially corresponding to a radially outward end of the bead filler 6.

According to the structure satisfying the above additional conditions, the tire weight is further reduced and the rolling resistance is more positively reduced to realize a lower fuel consumption of the vehicle.

The coefficient of rolling resistance between the invention tire and the comparative tire will be described with respect to the following comparative test.

◎ Tires to be tested have a tire size of 135/55R 16.

. Invention tire 1

It is a tire of Fig. 1 in which the ground contact width TW of the tread portion is 97 mm, the width of the inner belt layer 2a is 100 mm, the width of the outer belt layer 2b is 90 mm, the rubber gauge D of the tread portion is 5.8 mm, the thickness d of the belt is 2.3 mm, Young's modulus of cords in the auxiliary layer is 180

kg/mm^2, Young's modulus of cords in the belt layers is 1.8×10^4 kg/mm^2, and the periphery length ℓ of the auxiliary layer is 13 mm.

. Comparative tire 1

It is a tire having the same structure as in the invention tire 1 except that the auxiliary layer 3 is omitted.

. Comparative tire 2

It is a tire having the same structure as in the invention tire 1 except that the auxiliary layer 3 is omitted and the width of the inner belt layer is 110 mm.

◎ Test method

Each of the above tires is inflated under an internal pressure of 2.5 kgf/cm^2 and rotated on a rotating steel drum of 1707.6 mm in outer diameter and 400 mm in width having a smooth surface under a load L of 150 kgf as shown in Fig. 2, during which the coefficient of rolling resistance in a shaft for supporting the tire is measured according to the following equations:

$$\text{Rolling resistance } F_R = F_t \times (1 + rT/R_D)$$

$$\text{Coefficient of rolling resistance } RR_C = F_R/L \ (\times 10^{-4})$$

F_t: rolling resistance on the shaft - skim value
R_D: radius of the drum
rT: rotating radius of the tire under load
L : load

◎ Test result

The test results are indicated by an index on the basis that the comparative tire 1 is 100, and shown in Table 1. The smaller the index value, the better the result.

Table 1

	Comparative tire 1	Comparative tire 2	Invention tire 1
Coefficient of rolling resistance	100	95.5	82.1

As seen from Table 1, the coefficient of rolling resistance can largely be reduced in the invention tire 1 under the action of the belt 2 and the auxiliary layer 3 as compared with those of the comparative tires 1 and 2.

In Fig. 3 is schematically shown a second embodiment of the pneumatic radial tire according to the invention, which has substantially the same structure as in the first embodiment of Fig. 1 except for the followings.

That is, the tread portion 4 consists of a cap rubber 4a and a base rubber 4b having tan δ of 0.02-0.07, preferably 0.03-0.05. The ground contact width TW of the tread portion 4 is within a range of 0.55-0.70, preferably 0.60-0.65 of the maximum tire width SW, and the rubber gauge D of the tread portion 4 is within a range of 0.05-0.08, preferably 0.065-0.075 of the tire height SH. Further, the sidewall portion 8 has a rubber gauge t of 1.0-2.5 mm, preferably 1.5-2.2 mm and tan δ of 0.02-0.15, preferably 0.05-0.09.

Furthermore, this tire is provided at its innermost side with a contoured innerliner 10 of brominated butyl rubber having an air barriering property, in which a thickness of thinnest portion is 0.2-0.7 mm, preferably 0.3-0.4 mm.

According to this tire, the tire weight and the rolling resistance can effectively be reduced to realize the low fuel consumption. Furthermore, the internal loss can be more reduced because the minimum thickness of the innerliner 10 is 0.2-0.7 mm.

In order to more reduce the rolling resistance of the above tire, the height h of the bead filler 6 is made lower than the height H of the rubber chafer 7 and the volume ratio of the bead filler 6 to the rubber chafer 7 is within a range of 10-40%, preferably 20-30% likewise the first embodiment. Thus, the cut resistance can be enhanced by making the height H of the rubber chafer 7 higher, and also the rolling resistance of the tire can effectively reduced by making the volume of the bead filler 6 having a large tan δ sufficiently smaller than

that of the rubber chafer 7.

The rolling resistance and resistance to air leakage between the invention tire and the comparative tire will be described with respect to the following comparative test.

◎ Tires to be tested have a tire size of 175/70R 13 and are mounted onto a rim of 5J x 13 under an internal pressure of 2.5 kgf/cm^2.

. Invention tire 2

It is a tire shown in Fig. 3, in which the carcass 1 is comprised of polyethylene terephthalate fiber cords of 1000d/2, each of the belt layers 2a, 2b is comprised of 1x4 steel cords arranged at a cord angle of 20° with respect to the circumferential direction of the tire, the ratio of ground contact width TW of the tread portion (= 114 mm) to the maximum tire width SW (= 175 mm) is 0.651, the ratio of rubber gauge D of tread portion (= 7 mm) to tire height SH (= 123 mm) is 0.057, tan δ of base rubber of tread portion is 0.03, the innerliner 10 is made from brominated butyl rubber and has a minimum thickness of 0.3 mm, the height h of the bead filler 6 is 15 mm, the height H of the rubber chafer 7 is 32 mm, and the volume ratio of bead filler to rubber chafer is 26%.

. Comparative tire 3

It is a tire having the same structure as in the invention tire 2 except that tan δ of base rubber in the tread portion is 0.08, tan δ of rubber in the sidewall portion is 0.15 and the innerliner is made from chlorinated butyl rubber and has a minimum thickness of 0.8 mm.

◎ Test methods

The rolling resistance is evaluated by an inertial running proces after the tire is rotated on a rotating steel drum of 1707.6 mm in outer diameter and 350 mm in width having a smooth surface at a speed of 0-180 km/hr under a load of 300 kg.

The resistance to air leakage is evaluated by observing a change of internal pressure after being left to stand at a state of mounting on the rim for 3 months.

◎ Test results

The test results are shown in Table 2 by an index value. The larger the index value, the better the result.

Table 2

	Comparative tire 3	Invention tire 2
Rolling resistance	100	108
Resistance to air leakage	100	100

As seen from Table 2, the invention tire 2 can maintain the resistance to air leakage equal to that of the comparative tire 3 even if the thickness of the innerliner is made thin, while the tire weight and the internal loss are reduced to effectively reduce the rolling resistance.

In Fig. 4 is schematically shown a third embodiment of the pneumatic radial tire according to the invention, which has substantially the same structure as in the second embodiment except for the following condition.

In the belt 2 of this tire, the radially inner belt layer 2a is comprised of steel cords, and the radially outer belt layer 2b is comprised of organic fiber cords and folded at both ends outward in the radial direction of the tire and inward in the widthwise direction of the tread portion.

According to the tire of the third embodiment, the tire weight and the rolling resistance can effectively be reduced to satisfactorily realize the low fuel consumption.

The rolling resistance and road noise between the invention tire and the comparative tire will be described with respect to the following comparative test.

⓪ Tires to be tested have a tire size of 195/65R 14 and are mounted onto a rim of 6J x 14 under an internal pressure of 2.0 kgf/cm^2.

. Invention tire 3

It is a tire shown in Fig. 4, in which the carcass 1 is comprised of polyethylene terephthalate fiber cords of 1000d/2, the ratio of ground contact width TW of the tread portion (= 137 mm) to the maximum tire width SW (= 200 mm) is 0.685, the ratio of rubber gauge D of tread portion (= 8 mm) to tire height SH (= 125 mm) is 0.064, tan δ of base rubber of tread portion is 0.03, the,sidewall portion 8 has a rubber gauge t of 2.2 mm and tan δ of 0.07, the radially inner belt layer 2a is comprised of 1x4 steel cords arranged at a cord angle of 20° with respect to the circumferential direction of the tire, the radially outer belt layer 2b is comprised of aromatic polyamide fiber cords of 1500d/2 arranged at a cord angle of 20° with respect to the circumferential direction and folded at both ends inward in the widthwise direction of the tire, the innerliner 10 is made from brominated butyl rubber and has a minimum thickness of 0.3 mm, the height h of the bead filler 6 is 15 mm, the height H of the rubber chafer 7 is 32 mm, and the volume ratio of bead filler to rubber chafer is 26%.

. Comparative tire 4

It is a tire having the same structure as in the invention tire 3 except that tan δ of base rubber in the tread portion is 0.08, tan δ of rubber in the sidewall portion is 0.16, each of the inner and outer belt layers is comprised of 1x4 steel cords, and the innerliner is made from chlorinated butyl rubber and has a minimum thickness of 0.8 mm.

⓪ Test methods

The rolling resistance is evaluated by an inertial running proces after the tire is rotated on a rotating steel drum of 1707.6 mm in outer diameter and 350 mm in width having a smooth surface at a speed of 0-180 km/hr under a load of 400 kg.

The road noise is evaluated by measuring noise inside compartment at a position corresponding to a left ear of a driver when the tire is mounted on a vehicle having a displacement of 1600 cc and run on rough road surface at a speed of 60 km/hr.

⓪ Test results

The rolling resistance of the invention tire 3 is 105 as an index value when the rolling resistance of the comparative tire 4 is 100. In this case, the larger the index value, the better the result.

As to the road noise, sound pressure distribution of frequency is obtained as shown by a graph in Fig. 5, from which it is apparent that the sound pressure level as an over-all value in the invention tire 3 is lower by 1 dB than that of the comparative tire 4.

As seen from the above results, the rolling resistance and road noise can effectively be reduced in the invention tire 3.

In Fig. 6 is schematically shown a fourth embodiment of the pneumatic radial tire according to the invention, which has substantially the same structure as in the second embodiment except the following conditions.

In this tire, the rubber gauge h1 at a position B separated from a ground contact end A of the tread portion toward the bead portion at a distance as a periphery length of 3-10 mm is within a range of 60-70% of the rubber gauge D of the tread portion 4 and the rubber gauge h2 at a position C further separated from the above position B toward the bead portion at a distance corresponding to 12-17% of a periphery length ranging from a contact end E of the bead portion with a rim flange 11 to the contact end A of the tread portion is within a range of 40-50% of the rubber gauge D of the tread portion, whereby the rubber gauge is gradually changed between the positions B and C.

According to the tire of the above structure, the thinned portion between the positions B and C is easily deformed to mitigate strain energy, whereby the rolling resistance is effectively reduced.

In the illustrated embodiment, the thinned portion between the positions B and C is somewhat dented as compared with the other portions to form a recess as an annular groove. However, the thinned portion can smoothly connected to the other portions without denting as shown in Fig. 7a, or the thinned portion can smoothly connected to the other portions through a protruding decoration line arranged at a radially inward end of the thinned portion as shown in Fig. 7b. The latter cases can develop the same function and effect as in the above embodiment.

The rolling resistance and ride comfortability between the invention tire and the comparative tire will be described with respect to the following comparative test.

◎ Tires to be tested have a tire size of 155/65R 12 and are mounted onto a rim of 4x1/2J x 12 under an internal pressure of 2.5 kgf/cm^2.

. Invention tire 4

It is a tire shown in Fig. 6, in which the carcass 1 is comprised of polyethylene terephthalate fiber cords of 1000d/2, each of the inner and outer belt layers is comprised of 1x4 steel cords arranged at a cord angle of 20° with respect to the circumferential direction, tan δ at 90°C of cap rubber in the tread portion is 0.11, the rubber gauge of the sidewall portion is 2.2 mm, the ratio of ground contact width TW of the tread portion (= 95 mm) to the maximum tire width SW (= 157 mm) is 0.605, the ratio of rubber gauge D of tread portion (= 7 mm) to tire height SH (= 98.3 mm) is 0.071, the distance of the thinned portion from the ground contact end A to the position B is 7 mm, the rubber gauge h1 at the position B is 65% of the rubber gauge D of the tread portion, the distance from the position B to the position C is 14% of the periphery length (85 mm) between the positions A and E and the rubber gauge h2 at the position C is 43% of the rubber gauge D, the height h of the bead filler 6 is 15 mm, the height H of the rubber chafer 7 is 32 mm, and the volume ratio of bead filler to rubber chafer is 26%.

. Comparative tire 5

It is a tire having the same structure as in the invention tire 4 except that the thinned portion is omitted, which corresponds to the aforementioned invention tire 2.

◎ Test methods

The rolling resistance is evaluated by an inertial running proces after the tire is rotated on a rotating steel drum of 1707.6 mm in outer diameter and 350 mm in width having a smooth surface at a speed of 0-180 km/hr under a load of 400 kg.

The ride comfortability is evaluated by a feeling test of a driver when the tire is actually run on rough road.

◎ Test results

The test results are shown in Table 3 by an index value. Moreover, the larger the index value, the better the result.

Table 3

	Rolling resistance	Ride comfortability
Comparative tire 5	100	100
Invention tire 4	103	103

As seen from Table 3, in the invention tire 4, the rolling resistance and ride comfortability can more effectively be improved as compared with the comparative tire 5 or the invention tire 2.

As mentioned above, according to the invention, the rolling resistance of the tire as well as the reduction of the tire weight can effectively be reduced to sufficiently realize the low fuel consumption and also the reduction of road noise and the improvement of ride comfortability can satisfactorily be attained.

Claims

1. A pneumatic radial tire comprising a tread portion (4) of cap and base structure, a pair of sidewall portions (8) extending inward from tread ends in the radial direction of the tire, a pair of bead portions extending from the sidewall portions, a carcass (1) of at least one carcass ply extending between the bead portions and containing cords substantially arranged at an angle of 90° with respect to the circumferential direction

of the tire, a belt (2) of two belt layers (2a, 2b) each containing cords arranged at a relatively small cord angle with respect to the circumferential direction, cords of which layers being crossed with each other, and at least one auxiliary layer (3) disposed on each side portion of the belt (2) and extending toward a sidewall portion (8) over a position of maximum width of the belt, characterized in that the belt (2) has a width (BW) corresponding to 70-110% of a ground contact width (TW) of the tread portion (4), and the tread portion has a rubber gauge (D) corresponding to not more than 4.5 times the thickness (d) of the belt (2), and the auxiliary layer (3) is comprised of cords substantially extending in the circumferential direction, in which a Young's modulus of the cord is less than that of the cord in the belt and a peripheral length (ℓ) of a portion extending from the maximum width of the belt toward the sidewall portion (8) in the auxiliary layer (3) is within a range of 8-15% of the width (BW) of the belt.

2. A pneumatic radial tire as claimed in claim 1, characterized in that said ground contact width (TW) of the tread portion (4) is within a range of 0.55-0.70 of the maximum width (SW) of the tire, and said rubber gauge (D) of the tread portion (4) is within a range of 0.05-0.08 of a tire height (SH) as measured from a bead base of the bead portion, and a base rubber (4b) of the tread portion (4) has tan δ of 0.02-0.07, and the sidewall portion (8) has a rubber gauge (t) of 1.0-2.5 mm and tan δ of 0.02-0.15, and said tire is further provided at its innermost side with an inner liner (10) made from brominated butyl rubber and having a thinnest portion of 0.2-0.7 mm.

3. A pneumatic radial tire as claimed in claim 1 or 2, characterized in that said belt (2) comprises a radially inner belt layer (2a) comprised of steel cords and a radially outer belt layer (2b) comprised of organic fiber cords and folded at its side ends inward in the widthwise direction of the tread portion.

4. A pneumatic radial tire as claimed in any of claims 1 to 3, characterized in that a rubber gauge (h1) at a position (B) separated from a ground contact end (A) of the tread portion toward the bead portion at a distance as a peripheral length of 3-10 mm is within a range of 60-70% of the rubber gauge (D) of the tread portion (4), and a rubber gauge (h2) at a position (C) further separated from the said position (B) toward the bead portion at a distance corresponding to 12-17% of a peripheral length ranging from a contact end (E) of the bead portion with a rim flange (11) to the contact end (A) of the tread portion is within a range of 40-50% of the rubber gauge (D) of the tread portion (4).

5. A pneumatic radial tire comprising a tread portion (4) of cap and base structure, a pair of sidewall portions (8) extending inward from tread ends in the radial direction of the tire, a pair of bead portions extending from the sidewall portions, a carcass (1) of at least one carcass ply extending between the bead portions and containing cords substantially arranged at an angle of 90° with respect to the circumferential direction of the tire, a belt (2) of two belt layers (2a, 2b) each containing cords arranged at a relatively small cord angle with respect to the circumferential direction, cords of which layers being crossed with each other, and an inner liner (10), characterized in that a ground contact width (TW) of the tread portion (4) is within a range of 0.55-0.70 of the maximum width (SW) of the tire, and a rubber gauge (D) of the tread portion (4) is within a range of 0.05-0.08 of a tire height (SH) as measured from a bead base of the bead portion, and a base rubber (4b) of the tread portion (4) has tan δ of 0.02-0.07, and the sidewall portion (8) has a rubber gauge (t) of 1.0-2.5 mm and tan δ of 0.02-0.15, and the inner liner (10) is made from brominated butyl rubber and has a thinnest portion of 0.2-0.7 mm.

6. A pneumatic radial tire as claimed in claim 5, characterized in that said belt (2) comprises a radially inner belt layer (2a) comprised of steel cords and a radially outer belt layer (2b) comprised of organic fiber cords and folded at its side ends inward in the widthwise direction of the tread portion.

7. A pneumatic radial tire as claimed in claim 5 or 6, characterized in that a rubber gauge (h1) at a position (B) separated from a ground contact end (A) of the tread portion toward the bead portion at a distance as a peripheral length of 3-10 mm is within a range of 60-70% of the rubber gauge (D) of the tread portion (4), and a rubber gauge (h2) at a position (C) further separated from the said position (B) toward the bead portion at a distance corresponding to 12-17% of a peripheral length ranging from a contact end (E) of the bead portion with a rim flange (11) to the contact end (A) of the tread portion is within a range of 40-50% of the rubber gauge (D) of the tread portion (4).

8. A pneumatic radial tire as claimed in any of claims 5 to 7, characterized in that said belt (2) comprises a radially inner belt layer (2a) comprised of steel cords and a radially outer belt layer (2b) comprised of organic fiber cords and folded at its side ends inward in the widthwise direction of the tread portion, and a

rubber gauge (h1) at a position (B) separated from a ground contact end (A) of the tread portion toward the bead portion at a distance as a peripheral length of 3-10 mm is within a range of 60-70% of the rubber gauge (D) of the tread portion (4), and a rubber gauge (h2) at a position (C) further separated from the said position (B) toward the bead portion at a distance corresponding to 12-17% of a peripheral length ranging from a contact end (E) of the bead portion with a rim flange (11) to the contact end (A) of the tread portion is within a range of 40-50% of the rubber gauge (D) of the tread portion (4), and at least one auxiliary layer (3) is disposed on each side portion of the belt (2) so as to extend toward a sidewall portion (8) over a position of maximum width of the belt and is comprised of cords substantially extending in the circumferential direction, in which a Young's modulus of the cord is less than that of the cord in the belt and a peripheral length (ℓ) of a portion extending from the maximum width of the belt toward the sidewall portion (8) in the auxiliary layer (3) is within a range of 8-15% of the width (BW) of the belt.

9. A pneumatic radial tire comprising a tread portion (4) of cap and base structure, a pair of sidewall portions (8) extending inward from tread ends in the radial direction of the tire, a pair of bead portions extending from the sidewall portions, a carcass (1) of at least one carcass ply extending between the bead portions and containing cords substantially arranged at an angle of 90° with respect to the circumferential direction of the tire, a belt (2) of two belt layers (2a, 2b) each containing cords arranged at a relatively small cord angle with respect to the circumferential direction, cords of which layers being crossed with each other, and an inner liner (10), characterized in that a ground contact width (TW) of the tread portion is within a range of 0.55-0.70 of the maximum width of the tire, and a rubber gauge (D) of the tread portion (4) is within a range of 0.05-0.08 of a tire height (SH) as measured from a bead base of the bead portion, and a base rubber (4b) of the tread portion has a tan δ of 0.02-0.07, and the sidewall portion (8) has a rubber gauge (t) of 1.0-2.5 mm and tan δ of 0.02-0.15, and a radially inner belt layer (2a) of the belt is comprised of steel cords and a radially outer belt layer (2b) thereof is comprised of organic fiber cords and is folded at its side ends inward in the widthwise direction of the tread portion, and the inner liner (10) is made from brominated butyl rubber and has a thinnest portion of 0.2-0.7 mm.

10. A pneumatic radial tire as claimed in claim 9, characterized in that a rubber gauge (h1) at a position (B) separated from a ground contact end (A) of the tread portion toward the bead portion at a distance as a peripheral length of 3-10 mm is within a range of 60-70% of the rubber gauge (D) of the tread portion (4), and a rubber gauge (h2) at a position (C) further separated from the said position (B) toward the bead portion at a distance corresponding to 12-17% of a peripheral length ranging from a contact end (E) of the bead portion with a rim flange (11) to the contact end (A) of the tread portion is within a range of 40-50% of the rubber gauge (D) of the tread portion (4).

11. A pneumatic radial tire comprising a tread portion (4), a pair of sidewall portions (8) extending inward from tread ends in the radial direction of the tire, a pair of bead portions extending from the sidewall portions, a carcass (1) of at least one carcass ply extending between the bead portions and containing cords substantially arranged at an angle of 90° with respect to the circumferential direction of the tire, and a belt (2) of two belt layers (2a, 2b) each containing cords arranged at a relatively small cord angle with respect to the circumferential direction, cords of which layers being crossed with each other, characterized in that a ground contact width (TW) of the tread portion is within a range of 0.55-0.70 of the maximum width (SW) of the tire, and a rubber gauge (D) of the tread portion (4) is within a range of 0.05-0.08 of a tire height (SH) as measured from a bead base of the bead portion, and a rubber of the tread portion has tan δ of 0.02-0.07, and the sidewall portion (8) has a rubber gauge (t) of 1.0-2.5 mm, and a rubber gauge (h1) at a position (B) separated from a ground contact end (A) of the tread portion toward the bead portion at a distance as a peripheral length of 3-10 mm is within a range of 60-70% of the rubber gauge (D) of the tread portion (4), and a rubber gauge (h2) at a position (C) further separated from the said position (B) toward the bead portion at a distance corresponding to 12-17% of a peripheral length ranging from a contact end (E) of the bead portion with a rim flange (11) to the contact end (A) of the tread portion is within a range of 40-50% of the rubber gauge (D) of the tread portion (4).

FIG_1

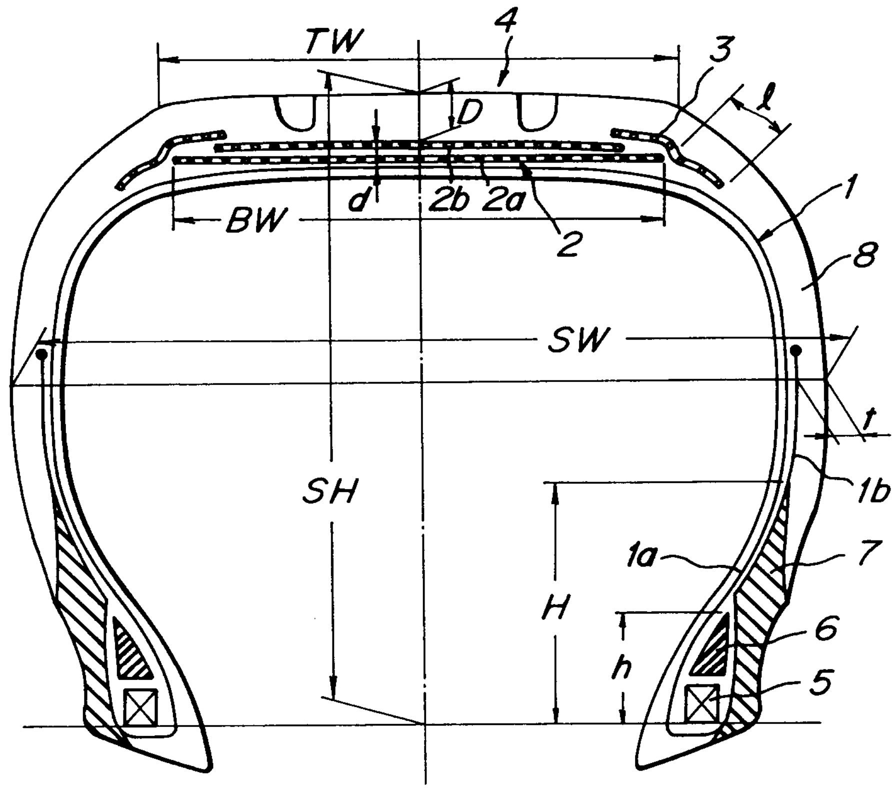

TW
4
3
ℓ
D
d
2b
2a
BW
2
1
8
SW
t
SH
1b
1a
7
H
6
h
5

FIG_2

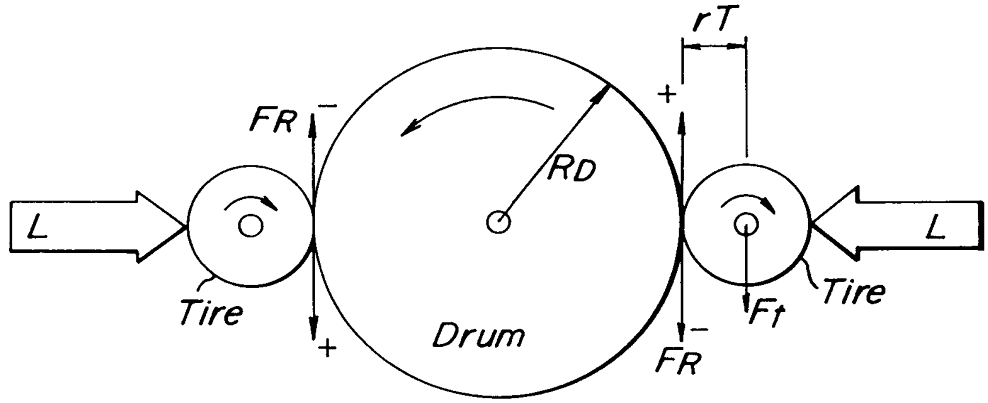

rT
FR
RD
L
Tire
Drum
Ft
FR
Tire
L

FIG_3

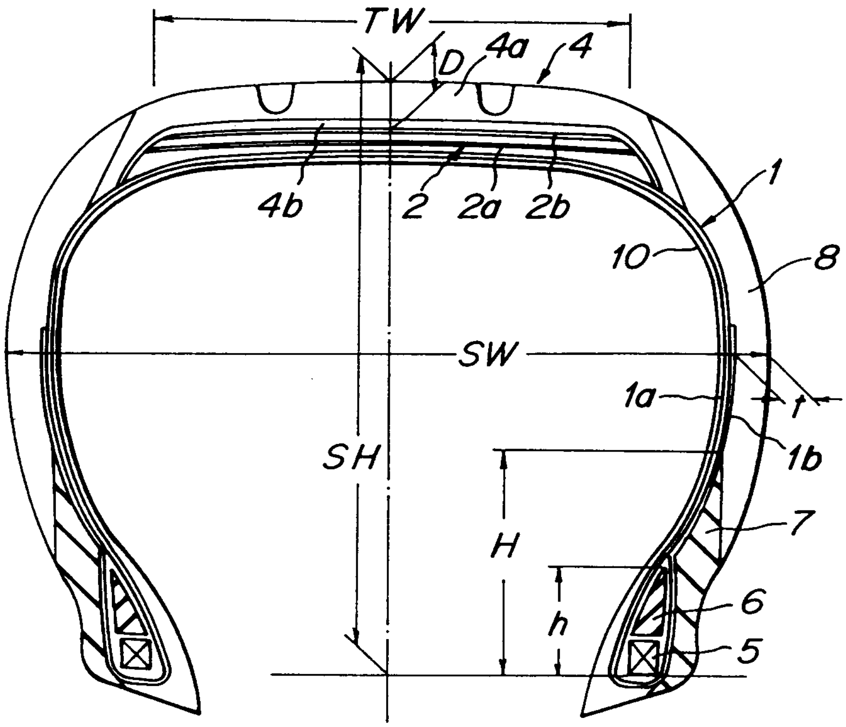


FIG_4

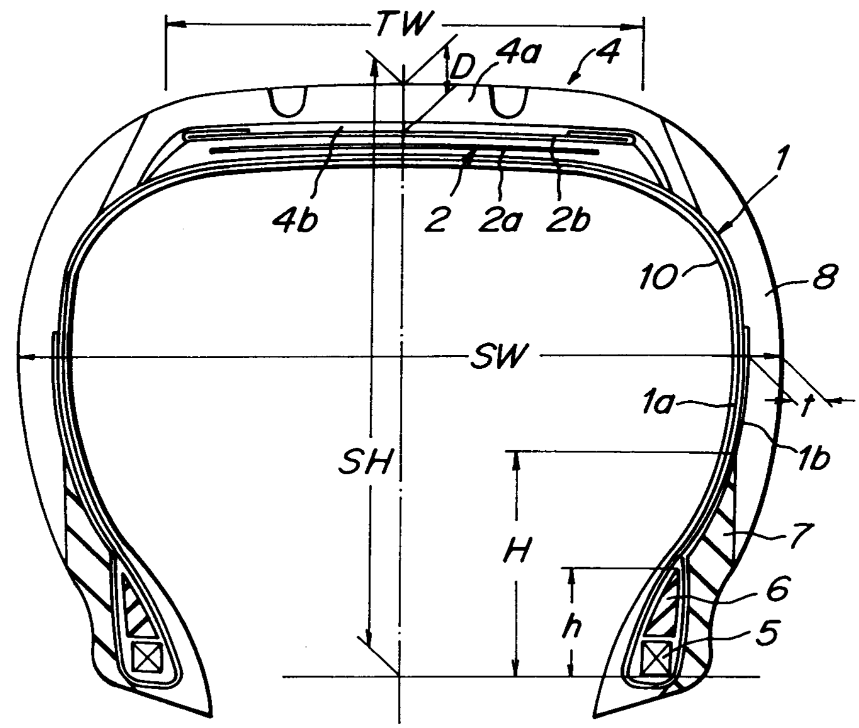

TW
D
4a
4
4b
2
2a
2b
1
10
8
SW
t
1a
1b
SH
H
7
6
h
5

FIG_5

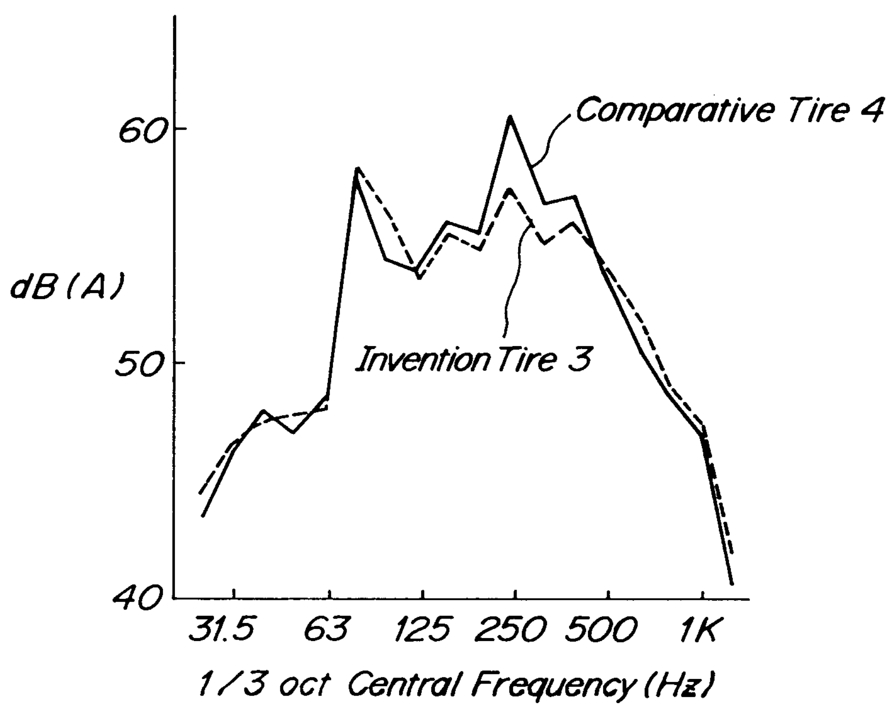

Comparative Tire 4
60
dB(A)
50
Invention Tire 3
40
31.5
63
125
250
500
1K
1/3 oct Central Frequency (Hz)

FIG. 6

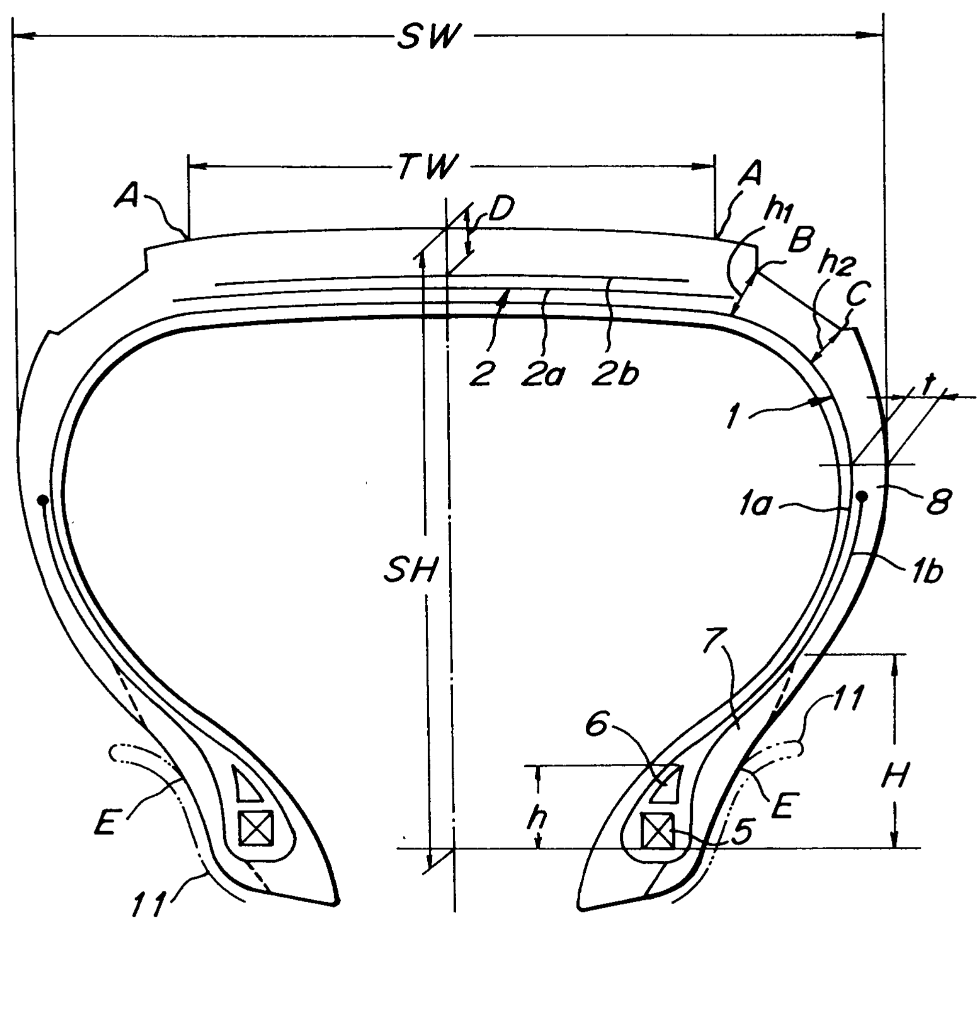


FIG_7a

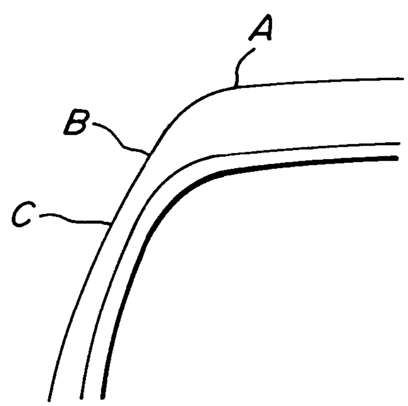
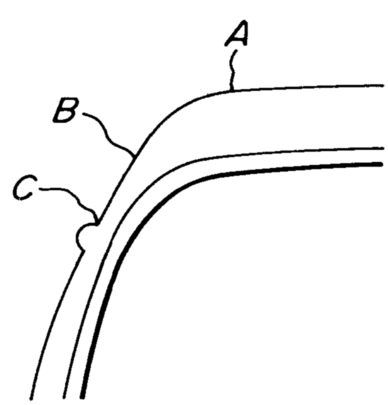


FIG_7b



European Patent Office

EUROPEAN SEARCH REPORT

Application Number

EP 93 30 0663

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
Y	EP-A-0 119 152 (THE GOODYEAR TIRE&RUBBER CO.) * the whole document *	11	B60C11/00 B60C3/04
A		1,2,4,5, 7-10	
Y	EP-A-0 413 574 (SUMITOMO RUBBER INDUSTRIES LTD.) * page 3, line 34 - line 54; claims; figure 1; table 1 *	11	
A	EP-A-0 435 620 (SUMITOMO RUBBER INDUSTRIES LTD.) * page 2; claims; figures; tables *	1,5,9,11	
A	FR-A-1 586 370 (UNIROYAL ENGLEBERT FRANCE S.A.) * page 4, line 12 - page 5, line 11; figure 3 *	1,8	
A	EP-A-0 337 279 (HERCULES INC.) * examples 1,2 *	2,5,9	**TECHNICAL FIELDS SEARCHED (Int. Cl.5)**
A	EP-A-0 128 852 (THE GOODYEAR TIRE&RUBBER CO.)	1,5,9,11	B60C

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	13 MAY 1993	BARADAT J.L.

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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